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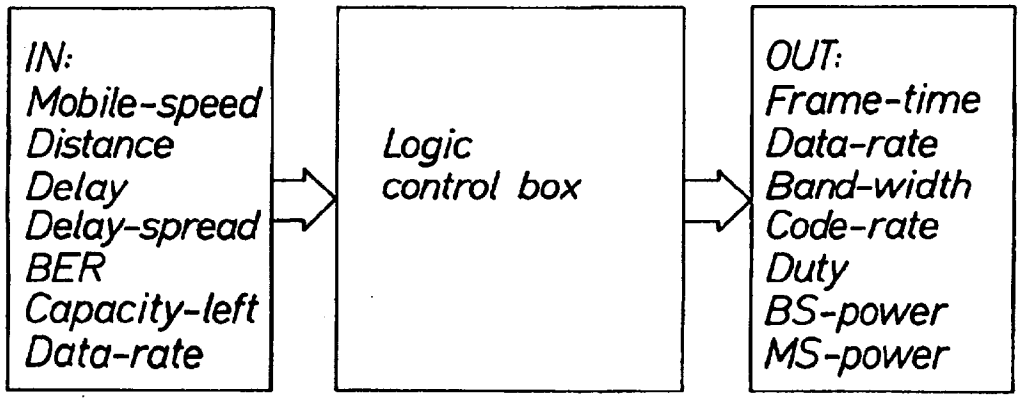
(54) Title: ADAPTIVE AIR INTERFACE



(57) Abstract

The invention relates to an adaptive air interface suitable for use in a cellular telecommunication system. The air interface contains various kinds of information elements having operating parameters such as framing data, synchronization data, information data and error control data. The adaptive air interface in accordance with the invention includes means for collecting parameter requirements, means for relating the parameter requirements to an input space, means for transforming the input space to an output space, the output space defining the operating parameters of the air interface. Preferably, the transformation means includes a fuzzy logic controller.

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TITLE OF INVENTION: ADAPTIVE AIR INTERFACE

FIELD OF THE INVENTION

The present invention relates to an adaptive air interface suitable for use in a cellular telecommunication system. The air interface is the hardware and software device providing means for communicating over the free space with a device containing exactly the same air interface. An air interface contains various kinds of information elements to make this possible such as framing data, synchronization data, information data and error control data.

STATE OF THE ART

Fixed parameters in the air interface are prevailing today, meaning that all parameters have to be decided and specified before building the system in hardware and software. This makes it inflexible and impossible to change parameters according to need, e.g. error control in severe environment or bandwidth and symbol rate, if necessary and according to need.

The present invention solves the above-mentioned problem by providing an air interface that is adapted to various requirements in dependence of the current operating conditions and needs.

SUMMARY OF THE INVENTION

Thus, the adaptive air interface in accordance with the invention includes means for collecting parameter requirements, means for relating the parameter requirements to an input space, means for transforming the input space to an output space, the output space defining the operating parameters of the air interface.

The invention is set forth in detail in the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is described in greater detail below with reference to the attached drawings, in which

Figure 1 is a block diagram of the transformation of the input space to the output space in accordance with the invention,

Figure 2 is a block diagram of the fuzzy logic control in accordance with the invention,

Figures 3A to F are diagrams of the input variable membership functions, and

Figures 4A to F are diagrams of the output variable membership functions.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The air interface in accordance with the present invention is described with respect to a mobile telecommunication system below, but is equally applicable to other air interfaces as is appreciated by a person skilled in the art. The adaptive air interface contains a number of parameters and schemes that are controlled adaptively. Some of the properties of the adaptive air interface are

- TDMA or FH-TDMA (Frequency Hopping Time Division Multiple Access)
- Frame period 0.5-2 ms basic, x (1/8, 1/4, 1/2, 2, 4) adaptively determined
- Fast power control each burst
- Mobile station (MS) return channel response each burst
- Net data rates: 32, 64, 128, 144, 192, 384 kb/s
- Modulation schemes 2-16 PSK; QPSK, 8PSK/2AM, 16QAM, 64QAM
- FEC and/or Turbo coding
- Software controlled parameters, partly by fuzzy logic
- Modulation bandwidth supported 25, 50, 100 and 200 kHz
- Frequency hopping mode to improve fading resistance and to improve C/I performance
- Supports 64 kb/s PCM and G722 high quality 20-7000 Hz voice coder, and primary rate 2B+D

- Adapts to 2-20 ms total processing delay requirements

Users are classified into 3 different categories
1. slow (stationary or walking) speed
2. medium (fast walking, slow car) speed
3. high (fast car) speed

The air interface according to the invention enables adaptivity according to situations and scenarios at hand. A number of possibilities arises namely with the following adaptable parameters in what is called the output space

- Frame time
- Data rate
- Bandwidth
- Code rate
- Duty factor
- Mobile station (MS) power
- Base station (BS) power

The decisions behind the parameters are based on measurements, user needs, operator considerations and given resources using an optimizing algorithm. These parameter requirements are collected by the interface. The requirements are related to the input data or the input space consisting of the following parameters

- Mobile speed
- Delay
- Distance
- Delay spread
- Capacity left in the mobile station
- BER (Bit Error Rate)

A number of examples are given and a device based on either finite state machine or a fuzzy logic solution is given to compute the parameters under various conditions.

In Figure 1 is shown a block diagram of the transformation of the input space to the output space. The input space is processed by a logic control box including rules for the transformation.

One approach to perform the transformation is by means of a finite state machine. A finite state machine has a

finite number of states of the input variables which are transformed by logic rules to output variables. Below is an example of logic rules in a finite state machine.

IF
{Mobile speed=Stationary
AND
Delay <6 ms
AND
Distance < 8 km
AND
Delay spread < 1 μs
AND
Capacity left > 0.4
AND
BER < $10\text{-}6^{-6}$}

THEN
{Frame time = 2ms
AND
Data rate = 144 kb/s
AND
Bandwidth = 100 kHz
AND
Code rate = 0.8
AND
Duty factor = 45%
AND
BS power = 22 dBm
AND
MS power = 6 dBm}

Another approach is to perform the transformation by means of a fuzzy logic controller. As opposed to the finite state machine, the fuzzy logic controller operates on a number of membership functions μ. For each variable a number of membership functions are defined. The membership functions may assume various values ranging from zero to one and not just the discrete numbers zero and one.

In Figures 3A to F a number of input variable membership functions are illustrated. As may be seen from the figures,

each input variable has a set of three membership functions taking on different values for a specific value on the x axis. The fuzzy logic controller contains rules for transforming the input membership functions to output membership functions. An example of output membership functions is illustrated in Figures 4A to F.

Thus, for each output variable a separate value of three output variable membership functions is obtained. The fuzzy logic controller also includes rules for "defuzzufication" which gives a crisp value on the x axis for the set of membership function values.

Since the output value that is to be used in the air interface only can assume fixed values a further quantizing operation takes place to obtain the crisp output variable. The defuzzufication operation and quantizing operation are illustrated in Figure 2.

The logic rules of the fuzzy logic controller, also called fuzzy rule base, are determined by detailed investigation of the particular problem at hand. There are commercially available computer-aided methods for defining, tuning and optimising the fuzzy rule base.

An example of fuzzy logic rules is given below.

IF
{Mobile speed = Low
AND
Delay = Medium
AND
Distance = Medium
AND
Delay spread = Small
AND
Capacity left = Medium
AND
BER = Small}

THEN

{Frame-time = Low
AND

Data rate = High
AND
Band width = Low
AND
Code rate = High
AND
Duty = Low
AND
BS power = Medium
AND
MS power = Medium

The quantizing operation is implemented according to the example below:

Let x be quantized according to $x = \{x_1, x_2, \ldots . x_n\}$. Input xc implies x_i, where $x_i < xc < x_i + 1$.

As an example the output variables can assume the following values:

- Frame time = {0,5, 1, 2, 4, 8} ms
- Data rate = {16, 32, 64, 128, 144, 192, 388} kb/s
- Bandwidth = {25, 50, 100, 200} kHz
- Code rate = {4/5, 3/4, 2/3, 1/2}
- Modulation scheme = {QPSK, 8PSK, 16QAM, 8CPM/TCM, 640QAM, 32QAM/TCM,...}
- Mode = {Normal, FH}
- BS power = {30, 28, 26,...} dBm

Optimization of output variables, according to selected cost functions, is performed in order to e.g. maximize quantities like capacity and throughput, minimize power from the base station and the mobile station. Optimization is performed on the following variables:

- Power consumption
- Spectrum usage
- Data rate
- Quality measured in BER (bit error rate)

The cost function CF is based upon the following rule

$$CF = \frac{\text{performance} \times \text{quality}}{\text{cost}}$$

$$\text{performance} = \text{data rate}$$

$$\text{quality} = -10 \times \log(\text{BER})$$

where cost is expressed as an inverse of spectrum usage × power consumption, i.e

$$\text{cost} \propto \frac{1}{\text{spectrum usage} \times \text{power consumption}}$$

CLAIMS

1. An adaptive air interface in a telecommunication system, **characterised** by means for collecting parameter requirements; means for relating the parameter requirements to an input space; means for transforming the input space to an output space, the output space defining the operating parameters of the air interface.

2. An adaptive air interface according to claim 1, **characterised** in that the collecting means is capable of collecting information about measurements, user needs, operator considerations and given resources.

3. An adaptive air interface according to claim 1 or 2, **characterised** in that the transformation means includes a finite state machine.

4. An adaptive air interface according to claim 1 or 2, **characterised** in that the transformation means includes a fuzzy logic controller defining membership functions (μ) of the input space and the output space and fuzzy rules determining transformation between the input and output space after an additional defuzzyficaton operation.

5. An adaptive air interface according to claim 4, **characterised** in that the fuzzy logic controller is capable of performing optimisation of the membership functions, the optimisation being based on a cost function (CF).

6. An adaptive air interface according to claim 5, **characterised** in that the cost function is based on the rule

$$CF = \frac{\text{performance} \times \text{quality}}{\text{cost}} \qquad \text{and}$$

$$\text{cost} \propto \frac{1}{\text{spectrum usage} \times \text{power consumption}}$$

7. An adaptive air interface according to any one of the preceding claims, **characterised** in that the input space includes the parameters: data rate, mobile speed, delay, distance from the base station, delay spread, capacity left in the base station, and bit error rate (BER).

8. An adaptive air interface according to claim 7, **characterised** in that the output space includes the parameters: frame time, modulation scheme, bandwidth, code rate, duty factor, base station power and mobile station power.

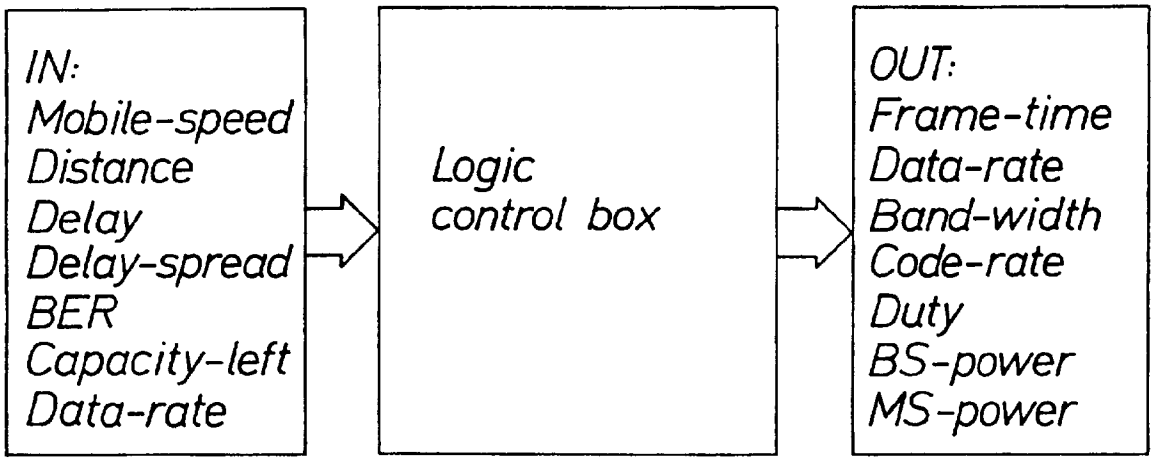
IN:
Mobile-speed
Distance
Delay
Delay-spread
BER
Capacity-left
Data-rate
Logic
control box
OUT:
Frame-time
Data-rate
Band-width
Code-rate
Duty
BS-power
MS-power

FIG. 1

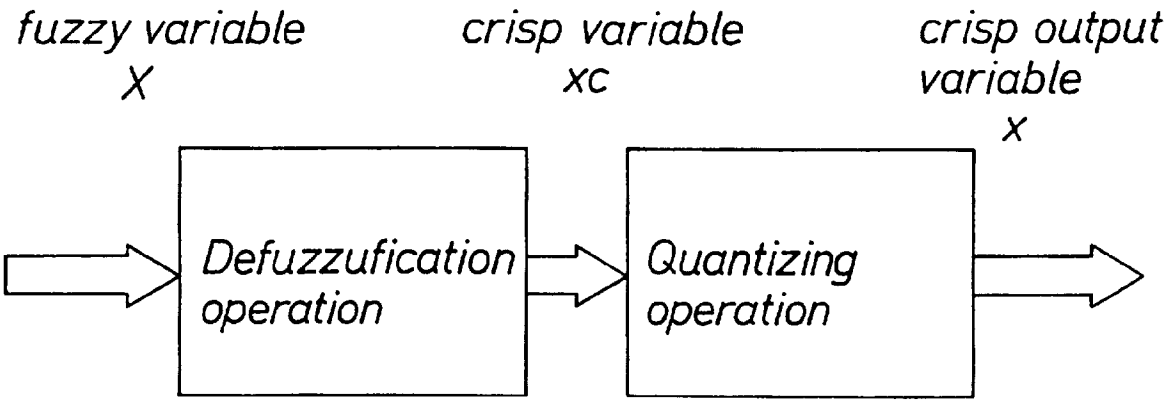
fuzzy variable
X
crisp variable
xc
crisp output
variable
x
Defuzzufication
operation
Quantizing
operation

FIG. 2

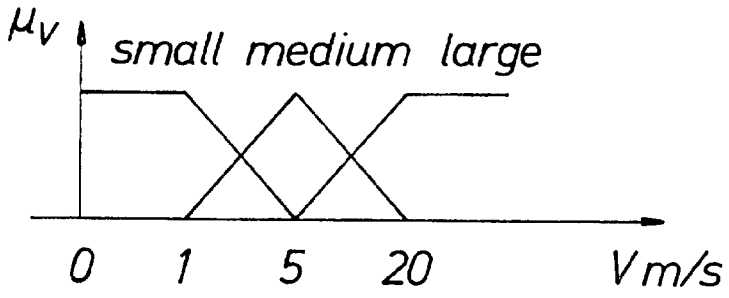

FIG. 3A

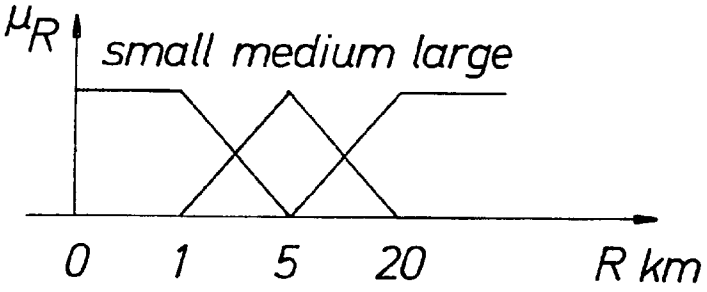

FIG. 3B

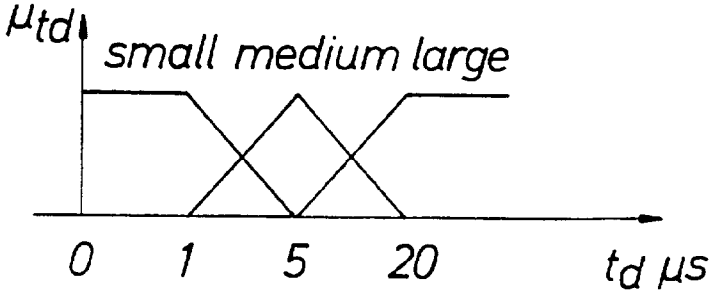

FIG. 3C

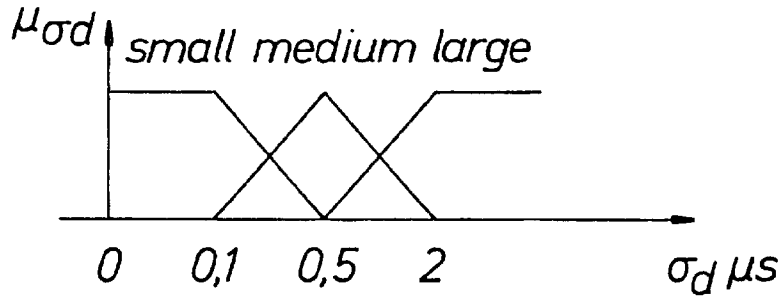

FIG. 3D

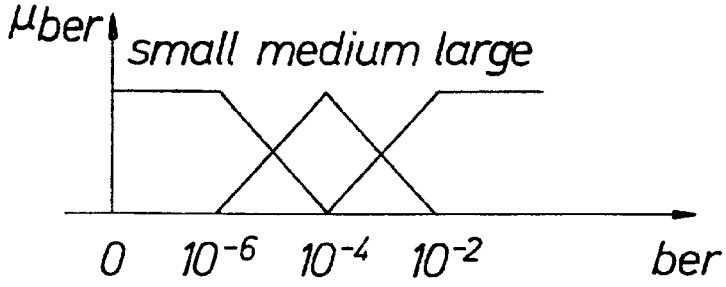

FIG. 3E

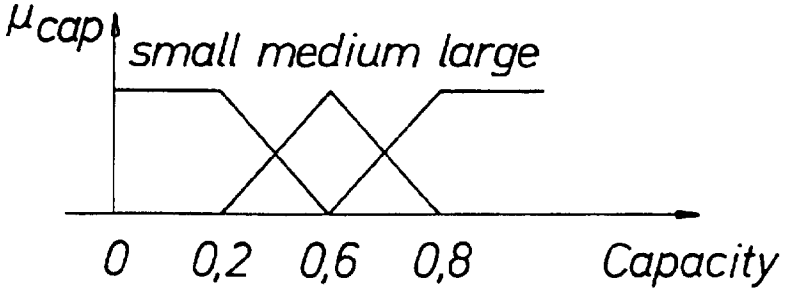

FIG. 3F

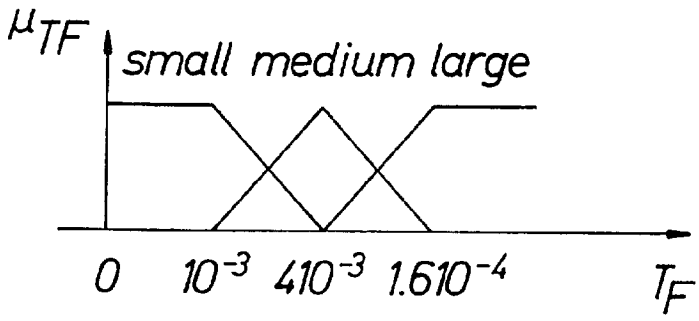

FIG. 4A

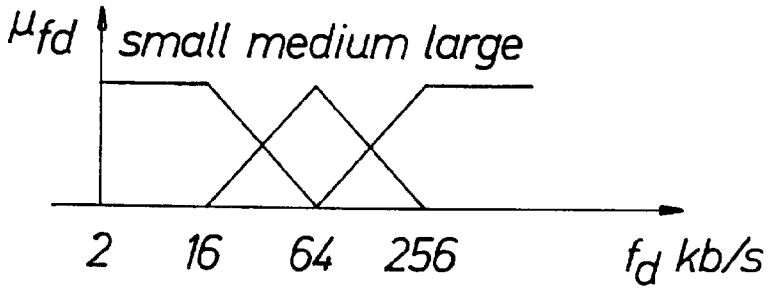

FIG. 4B

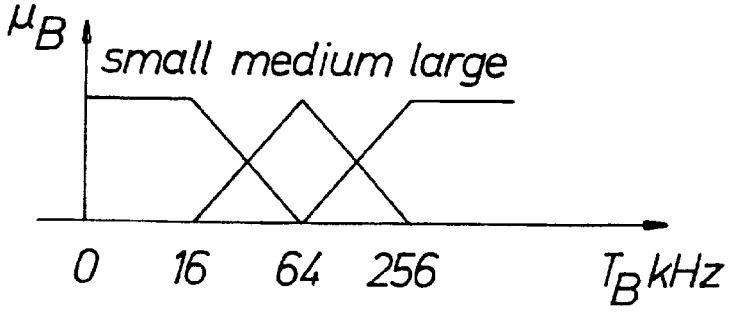

FIG. 4C

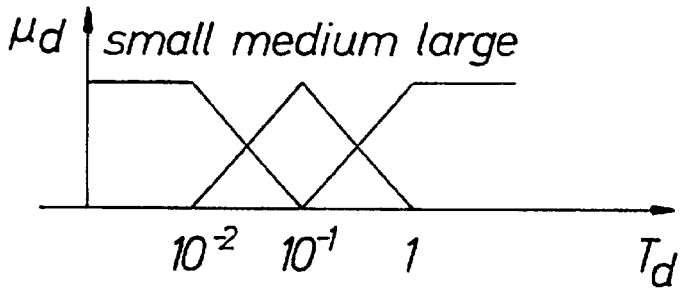

FIG. 4D

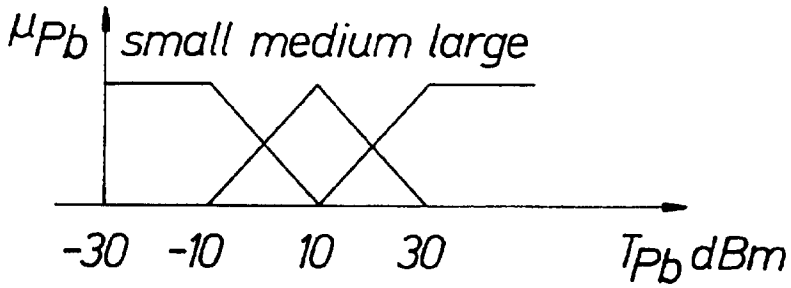

FIG. 4E

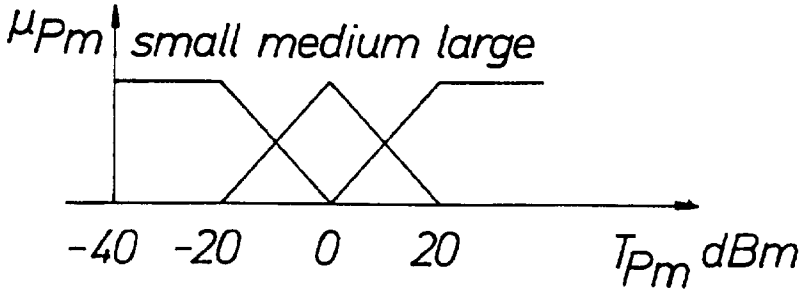

FIG. 4F

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00498

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04L 29/10, H04B 7/005
According to International Patent Classification (IPC) or to both national classification and IPC

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5425051 A (RONALD L. MAHANY), 13 June 1995 (13.06.95), column 1, line 41 - line 48; column 2, line 17 - line 36; column 2, line 65 - line 68, abstract, column 16, line 55 - column 17, line 5, column 17, line 30 - column 18, line 22	1-3,7,8
A	EP 0548939 A2 (NEC CORPORATION), 30 June 1993 (30.06.93), abstract	1-8
A	US 5446756 A (ALBERT J. MALLINCKRODT), 29 August 1995 (29.08.95), abstract	1-8

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4777653 A (GEORGES BONNEROT ET AL.), 11 October 1988 (11.10.88), abstract -- --------	1-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/07/97

International application No.
PCT/SE 97/00498

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